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Integrating Core Stability into the Otago Program for Fall Prevention in Older Women: A Quasi-Experimental Comparative Study

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Abstract

Background: With the global elderly population growing, falls are a significant cause of injury-related harm and death, leading to physical, psychological, and economic burdens. Key modifiable risks include poor balance, leg weakness, and fear of falling. While the Otago Exercise Program (OEP) reduces fall risk and core training improves stability, their combined effect is understudied. This study aimed to evaluate the impact of a modified OEP, incorporating core stability exercises, on fall risk, balance (static and dynamic), lower limb strength, and fear of falling in older women.

Methods: This quasi-experimental comparative study involved 30 community-dwelling women aged 65 to 80 years, assigned to 3 groups (n = 10 each): modified OEP (OEP + core training), original OEP, and control. The 8-week intervention included thrice-weekly sessions. Outcome measures included the Timed Up and Go (TUG) test for fall risk, the 4-Stage Balance Test for balance, the 30-Second Sit-to-Stand test for lower limb strength, and the Falls Efficacy Scale-International (FES-I) for fear of falling. Statistical analysis involved analysis of covariance and Bonferroni post hoc tests ($\alpha = 0.05$).

Results: After intervention, significant between-group differences were found across all outcome variables. The modified OEP group showed the most important improvements in fall risk ($F(2,26) = 25.7$; $P < 0.001$; $\eta^2 = 0.497$), dynamic and static balance ($F = 10.6$; $P = 0.003$; $\eta^2 = 0.291$), lower limb strength ($F = 22$; $P < 0.001$; $\eta^2 = 0.459$), and fear of falling ($F = 101.4$; $P < 0.001$; $\eta^2 = 0.796$). Bonferroni post hoc tests confirmed that the modified OEP group significantly outperformed both the original OEP and control groups in all measures ($P < 0.05$), and the original OEP group also showed significant improvements over the control.

Conclusion: Integrating core stability exercises into the OEP enhances its effectiveness, significantly improving fall risk, balance, lower limb strength, and fear of falling in older women. These findings support the use of integrated exercise programs in fall prevention.

Keywords: Falls prevention, Core stability, Otago Exercise Program, Balance, Elderly women

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Introduction

The global population is undergoing a rapid aging process, with projections estimating that the number of older adults will reach 2 billion by 2050, including approximately 25 million in Iran (1, 2). This demographic shift presents one of the significant challenges of the 21st century (3). Aging leads to physiological decline, such as impaired balance, altered gait, reduced muscle strength, and decreased physical function—factors that increase fall risk (4).

Falls are a leading cause of injury-related morbidity and

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↑What is "already known" in this topic:
Falls are a leading cause of injury and disability among older adults. Key modifiable risk factors include impaired balance, lower limb weakness, and fear of falling. The Otago Exercise Program (OEP) has proven effective in reducing fall risk, but evidence on the additional benefits of incorporating core-stability exercises remains limited.

→What this article adds:
This study demonstrates that adding core stability exercises to the OEP leads to greater improvements in fall risk, balance, lower limb strength, and fear of falling in older women, suggesting that this integrated approach may offer enhanced fall prevention benefits compared with the standard program.

mortality in adults aged ≥65 years, with around one-third of older people falling annually. Of those, 22% to 45% sustain injuries, and 10% experience severe complications such as fractures or traumatic brain injuries(5, 6). Beyond physical harm, falls contribute to significant psychosocial issues, including fear of falling, depression, social withdrawal, and reduced quality of life, while also driving up healthcare costs. As a result, fall prevention has become a critical public health priority (7).

The World Health Organization categorizes fall risk factors into biological, behavioral, environmental, and socioeconomic domains. Biological factors such as impaired postural balance, sensory deficits, muscle weakness, and reduced agility are key contributors (5). Fall prevention strategies often include lifestyle changes, such as nutrition, medication review, and stress management, as well as comprehensive medical management for those with comorbidities, such as osteoporosis or cardiovascular disease. However, physical exercise remains a cornerstone in fall prevention due to its well-documented benefits for musculoskeletal health, postural stability, and functional independence (7, 8).

Extensive evidence supports the effectiveness of exercise interventions in reducing fall risk, with reductions of up to 23% (6). Multicomponent programs that combine strength, balance, endurance, and flexibility have shown superior outcomes. The Otago Exercise Program (OEP), developed by the University of Otago, is particularly effective. It includes lower limb resistance training, balance exercises, and gait retraining, achieving up to a 35% reduction in fall incidence among individuals aged 65 and older (8, 9).

Core stability exercises have shown promise in enhancing postural control and reducing fall risk by targeting the abdominal, lumbar, hip, and gluteal muscles—critical for dynamic balance (10). This approach is based on Panjabi's 1992 model of spinal stability, which emphasizes the interaction among passive structures (bones and ligaments), active components (muscles), and neuromuscular control systems. Dysfunction in any of these subsystems can lead to instability and pain. Exercises like Pilates, yoga, and structured core stability training aim to improve stability, alleviate musculoskeletal pain, and enhance functional performance, offering particular benefits to older people by reinforcing key muscle groups for postural control (11).

Despite the demonstrated benefits of both OEP and core stability exercises, limited research has explored their integration. To our knowledge, this is the first study examining the potential synergistic effects of combining OEP with core stability training. Should our null hypothesis, that core stability exercises are not significantly more effective when integrated with OEP, be rejected, we anticipate observing superior and clinically meaningful improvements.

Therefore, the present study aimed to compare the effects of a modified OEP protocol incorporating core stability exercises with those of the traditional OEP on fall risk, fear of falling, static and dynamic balance, and lower limb strength among older women.

Methods

Study Design

This quasi-experimental study was conducted at the Shahrbanoo Cultural and Sports Center in Tehran (May-September 2023). All participants provided written informed consent after full disclosure of the protocol. The study was approved by the University of Tehran's Sport Sciences and Health Ethics Committee (IR.UT.SPORT.REC.1402.018, April 2023).

Participants

A total of 30 community-dwelling women aged 65 to 80 years were included. Participants were nonrandomly assigned to 1 of the 3 groups: modified OEP, original OEP,

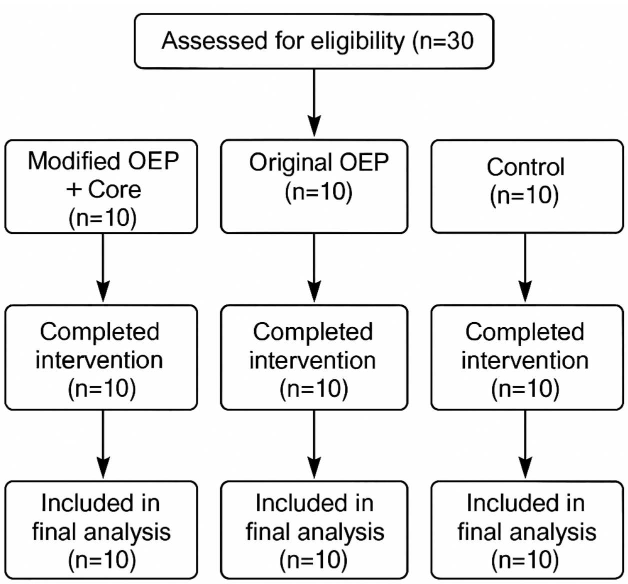

Figure 1. Participant flow in the quasi-experimental study

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or control (n = 10 per group), based on their availability and preferred training schedule (Figure 1). Group allocation was done using convenience sampling.

Medical history, including comorbidities, medication use, and fall history, was documented through self-report and review of available medical records.

Blinding and Bias

Due to the intervention's nature, blinding was not feasible, potentially leading to measurement bias. Also, selection bias may arise from the quasi-experimental design and convenience sampling. Key confounders were recorded and controlled where possible. Efforts to standardize procedures aimed to reduce bias. These limitations are acknowledged.

Sample Size Estimation

The required sample size was calculated using G*Power software with a significance level (α) of 0.05, power of 80% (1−β = 0.80), and an estimated effect size of 0.88 based on prior literature (12).

Although 36 participants were initially recruited to allow for potential attrition during eligibility screening, only 30 met the inclusion criteria and completed the baseline assessments (13).

Inclusion Criteria

Participants were required to meet the following criteria to be included in the study: community-dwelling older women aged between 65 and 80 years (14); willingness to participate; absence of musculoskeletal, neurological, or orthopedic disorders that could affect mobility or exercise participation; ability to walk independently without the use of assistive devices; no current engagement in regular physical activity; and a body mass index (BMI) within the normal range of 18 to 25 (15).

Exclusion Criteria

Participants were excluded from the study if they failed to comply with the intervention protocol, were absent from more than three scheduled training sessions, expressed unwillingness to continue participation at any stage, or sustained an injury during the intervention period that prevented further involvement.

Screening for orthopedic and neurological disorders was conducted through participant self-report questionnaires and clinicalinterviews performed by a qualified healthcare professional before enrollment to ensure eligibility.

Primary outcome

Fall Risk and Dynamic Balance

The Timed Up and Go (TUG) test assessed fall risk and dynamic balance by measuring the time (in seconds) taken for participants to stand from a standard chair (44-47 cm height), walk 3 meters, turn, walk back, and sit down, with 1 practice trial performed before timed testing (16). Normative values for healthy elderly are 8.1 seconds (60-69 years), 9.2 seconds (70-79 years), and 11.3 seconds (80-99 years) (14), with excellent reliability (interrater ICC, 0.98-0.99) in older populations (17).

Secondary Outcome

Static Balance

The 4-Stage Balance Test evaluated static balance using 4 progressively challenging stances (feet together, semi-tandem, tandem, and single-leg) held for 10 seconds each, performed with eyes open and closed (except single-leg stance, eyes open only), yielding seven trials scored 0-4 each (maximum total score = 28); inability to maintain tandem stance for ≥10 seconds indicates elevated fall risk (14, 18), while test-retest reliability shows moderate correlation (r= 0.66) over 3 to 4 months in community-dwelling older adults (19).

Lower Limb Strength

The 30-Second Sit-to-Stand test assessed lower limb strength and endurance by counting the maximum number of stand-sit repetitions completed in 30 seconds from a seated position with arms crossed, demonstrating excellent reliability (test-retest r = 0.89; 95% CI, 0.79-0.93) and strong validity through correlations with leg press performance and discriminative capacity across age/activity levels (20).

Fear of Falling

The Falls Efficacy Scale-International (FES-I) measures fear of falling through 16 items: 10 assess general fall efficacy, while 6 target activity-specific concerns (e.g., walking on slippery surfaces, visiting friends, or climbing slopes). Participants rate their concern on a 4-point Likert scale, with higher scores reflecting greater fear. The scale's construct validity was confirmed via Confirmatory Factor Analysis, and its convergent validity was supported by correlations with established fall-efficacy measures. Psychometric testing revealed excellent internal consistency (Cronbach's α > 0.80) and high test-retest reliability (ICC ≈ 0.90) (21).

Safety outcomes were monitored throughout the intervention, with supervising personnel overseeing sessions to record any adverse events such as discomfort, pain, or injury. No adverse events related to the exercise program were reported.

Interventions

In this study, both experimental groups participated in the OEP, a structured, progressive intervention designed to improve lower-limb strength, balance, and mobility and reduce fall risk. Participants trained three times per week over eight weeks (24 sessions total). Session duration was approximately 40 minutes for the original OEP group and 55 minutes for the Modified OEP group (core stability + OPE), each including a 10-minute warm-up and a 5-minute cool-down. The intervention adhered to the FITT principle: Frequency (3 sessions per week), Intensity (progressively increased based on performance), Time (40-55 minutes per session), and Type (balance, resistance, flexibility, and core exercises) (see Appendix for

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details). A qualified specialist at the Shahrbanoo Cultural and Sports Center supervised all sessions.

The standard OEP included exercises such as Sit-to-stand, Front knee and side hip strengthening, Calf and toe

Figure 2. Otago Exercise Program

raises, Knee bends, and gait and balance tasks, including Walking and turning, Backwards walking, Toe walk, Heel-toe walk, Heel-toe walking backwards, Heel-toe stand, and One-leg stand (Figure 2) (9). The modified OEP group completed the same protocol, with the addition of core stability exercises: curl-up, side bridge, and bird dog (quadruped) (Figure 3) (22).

Each core stability exercise was performed in 2 sets of 10-15 repetitions, with 30-45 seconds of rest between sets. Exercise progression was based on participants' tolerance and form quality, gradually increasing difficulty by modifying lever arms, reducing base of support, or increasing hold duration over the 8 weeks.

To ensure adherence and fidelity, session attendance was recorded for each participant, and the supervising instructor completed a structured checklist during each session, documenting completion of each exercise and any modifications or progression. Participants who missed more than 3 sessions were excluded from the final analysis. Reasons for dropout and withdrawal were recorded systematically.

The control group did not receive any exercise intervention and were instructed to continue their usual daily activities throughout the study period, without participation in any structured training sessions.

Statistical Methods

After data collection, SPSS version 26 was employed for descriptive and inferential statistical analysis. The Shapiro-Wilk test was utilized to assess the normality of the data and the feasibility of parametric tests. Subsequently, analysis of covariance (ANCOVA) was conducted to examine group differences at the 0.05 significance level.

Results

Baseline Characteristics

Baseline demographic characteristics of participants across the three groups are presented in Table 1. No statistically significant differences were observed among the modified OEP, original OEP, and control groups in age, height, weight, or BMI (all $P > 0.05$), indicating initial homogeneity among the groups.

Intervention Outcomes

After controlling for baseline values using ANCOVA, assumptions regarding homogeneity of regression slopes, normality of residuals, and homoscedasticity were tested and confirmed. Adjusted post-test means, controlling for baseline (pre-test) scores, accurately reflect group differences after covariate adjustment. Significant between-group differences were found in all outcome variables, including fall risk, dynamic balance, static balance, lower limb strength, and fear of falling. Detailed statistical outcomes are presented in Table 2.

While the raw pre- and post-test group means may appear to show minimal change (eg, 9.4 vs 9.5), the effect sizes and significance levels reflect adjusted post-test differences after controlling for pre-test values via ANCOVA. Therefore, the Bonferroni pairwise comparisons (eg, modified vs control = –3.86; $P < 0.001$) more accurately represent true between-group effects than raw mean differences.

Fall Risk and Dynamic Balance

Timed Up and Go (TUG) test scores, reflecting both fall risk and dynamic balance, showed a statistically significant group effect ($F(2, 26) = 25.7$; $P < 0.001$; $\eta^2 = 0.497$). Post hoc comparisons indicated that the Modified

Figure 3. Core stability Training

Table 1. Demographic characteristics of all participants (SD ± Mean)

Variable	Modified OEP* group (n=10)	Original OEP group (n=10)	Control group (n=10)	*P*-value
Age (year)	66.5±3.1	68.3±1.6	67.9±1.9	0.200
Height (meter)	160.6±6	162.7±4.6	162±4.4	0.600
Weight (kg)	62.1±4.7	65.1±3.8	62.8±3.2	0.200
BMI (kg/m²)	24±0.7	24.5±0.3	23.9±0.7	0.060

Table 2. ANCOVA and Bonferroni Post-Hoc Results with Adjusted Post-Test Differences (η² = Eta Squared)

Variable	Group	Pretest (Mean±SD)	Posttest (Mean±SD)	Bonferroni Comparison	Mean Diff.	*P*-value	Eta²
Fall Risk	Modified OEP	9.4±0.2	9.5±1.1	Modified vs. Original	-1.02	0.030	0.497
	Original OEP	10.4±0.2	10.5±1.0	Modified vs. Control	-3.86	<0.001	
	Control	13.2±0.2	12.9±1.2	Original vs. Control	-2.83	<0.001	
Dynamic Balance	Modified OEP	9.4±0.2	9.5±1.1	Modified vs. Original	-1.02	0.030	0.497
	Original OEP	10.4±0.2	10.5±1.0	Modified vs. Control	-3.86	<0.001	
	Control	13.2±0.2	12.9±1.2	Original vs. Control	-2.83	<0.001	
Static Balance	Modified OEP	26.0±0.7	26.0±2.1	Modified vs. Original	3.04	0.020	0.291
	Original OEP	23.0±0.7	22.8±3.2	Modified vs. Control	8.71	<0.001	
	Control	17.3±0.7	17.6±2.7	Original vs. Control	5.66	<0.001	
Lower Limb Strength	Modified OEP	14.3±0.3	14.3±1.7	Modified vs. Original	1.55	0.010	0.459
	Original OEP	12.7±0.3	12.5±1.3	Modified vs. Control	5.04	<0.001	
	Control	9.2±0.3	9.5±0.9	Original vs. Control	3.48	<0.001	
Fear of Falling	Modified OEP	19.9±0.5	20.3±2.4	Modified vs. Original	-1.96	0.030	0.796
	Original OEP	21.8±0.5	22.4±4.3	Modified vs. Control	-6.67	<0.001	
	Control	26.5±0.5	25.7±3.4	Original vs. Control	-4.70	<0.001	

OEP group outperformed both the original OEP ($P = 0.03$) and the control groups ($P < 0.001$), with the original OEP also significantly outperforming the control group ($P < 0.001$). These results suggest that adding core stability exercises enhances dynamic mobility and reduces fall risk more effectively than the standard program alone.

Static Balance

Group differences were also significant ($F(2, 26) = 10.6$; $P = 0.003$; $\eta^2 = 0.291$). The Modified OEP group achieved higher static balance scores than both the original OEP ($P = 0.02$) and the control groups ($P < 0.001$), and the original OEP group also outperformed the control group ($P < 0.001$).

Lower Limb Strength: A significant between-group difference was found ($F(2, 26) = 22$; $P < 0.001$; $\eta^2 = 0.459$). Post hoc results indicated that the Modified OEP group had significantly higher strength scores than the original OEP ($P = 0.007$) and the control groups ($P < 0.001$). Additionally, the original OEP group showed significantly better outcomes than the control group ($P < 0.001$).

Fear of Falling: This variable exhibited the largest effect size ($F(2, 26) = 101.4$; $P < 0.001$; $\eta^2 = 0.796$). The Modified OEP group demonstrated significantly reduced fear of falling relative to both the original OEP ($P = 0.03$) and control groups ($P < 0.001$). The original OEP group also showed a significant reduction compared to the control group ($P < 0.001$).

A comprehensive summary of the descriptive and inferential statistics, including pre- and post-test means, standard deviations, F-values, P values, effect sizes (η²), and Bonferroni-adjusted comparisons, is provided in Table 2.

Discussion

This study investigated the additive effects of core stability training within the OEP framework on fall risk, balance (static and dynamic), lower limb strength, and fear of falling in older women. The results demonstrated that the modified OEP, augmented with core stability exercises, was significantly more effective across all measured outcomes than the standard OEP or control conditions. Notably, large effect sizes for both fall risk and fear of falling suggest that the intervention's clinical relevance extends beyond statistical significance, supporting its potential utility in real-world geriatric settings.

Our findings align closely with a broad body of literature supporting the efficacy of the OEP in improving balance and reducing fall risk among older adults (4-6, 23-25). For instance, Yang et al (2022) found that the OEP significantly improved lower limb strength, postural control, and dynamic balance, results consistent with those of our study. Yang and colleagues also highlighted the uncertainty surrounding the neurophysiological mechanisms underlying these benefits, a limitation shared by our research, suggesting the need for future studies using neuroimaging or neurophysiological assessments to explore these mechanisms (26).

Our findings build on Chiu et al (2021), who reported significant effects of the OEP on both actual (static and dynamic balance) and perceived (balance confidence) balance performance (27). While replicating these improvements, our study also suggests that adding core-stability exercises enhances these benefits, especially in reducing fear of falling. While Chiu et al emphasized session duration and group format, our results indicate that the exercise content—specifically, core engagement—may be another important factor contributing to the program's effectiveness.

Genç and Bilgili (2023) similarly found significant improvements in functional mobility and balance in a nursing home-based OEP intervention, though upper extremity strength and aerobic capacity were unaffected (28). Our results align with this, showing improvements in lower limb strength and mobility, though upper limb outcomes were not assessed. Notably, our study extends this by demonstrating that core-focused adaptations can further enhance mobility and psychological resilience, areas not directly addressed in the Genç study.

The robust meta-analysis by Han et al (2024) provides compelling evidence that the OEP is particularly effective in reducing fear of falling when implemented for at least 24 weeks and more than twice weekly (29). While our study used a shorter (8-week) intervention, we still observed a significant reduction in fear of falling. This suggests that core stability exercises may accelerate these benefits. Han et al's subgroup analysis also supports the OEP's applicability across diverse older adult populations, aligning with the broad applicability of our intervention.

The study by Arnold et al (2015) presents a contrasting view, showing that adding core stability training to a standard balance program did not significantly improve functional outcomes like sit-to-stand repetitions (30). In contrast, our study found that integrating core stability into a multicomponent program like the OEP led to significant improvements in mobility, balance, and psychological outcomes. This discrepancy may stem from differences in intervention design, progression, or participant characteristics, highlighting the importance of program structure and exercise specificity in evaluating core stability's role in fall prevention.

Collectively, these findings suggest that integrating core stability training with the OEP produces synergistic benefits that exceed those of the traditional program. While the OEP is efficacious in improving physical function and reducing fall risk, adding core exercises enhances outcomes by addressing both physical impairments and fear-based limitations. This dual benefit is especially valuable in geriatric populations, where fear of falling often hinders physical activity and social engagement.

Despite its strengths, this study is not without limitations. The quasi-experimental design used convenience sampling without randomization, potentially introducing selection bias. The small sample size (n = 10 per group) restricts statistical power and limits generalizability, particularly across genders and ethnically diverse populations. Moreover, the short duration (eight weeks) may not reflect the full potential of the intervention, especially when compared to the longer durations (≥24 weeks) shown to be most effective in previous meta-analyses (Han et al, 2024) (29). Additionally, the lack of long-term follow-up precludes conclusions regarding the sustainability of the observed benefits. Finally, the homogeneity of the sample—older women without significant comorbidities—limits its applicability to more complex or frail populations.

Conclusion

This study provides preliminary evidence that adding core stability training to the OEP may improve fall risk, balance, lower limb strength, and fear of falling in older women. However, given the small sample size, the brief intervention, and the lack of follow-up, the results should be interpreted cautiously. Future studies with larger samples, longer follow-up, and greater duration are needed to confirm these findings and explore long-term effects.

Authors' Contributions

S.Z. conceptualized and designed the study as part of her Master's thesis project. H.M. supervised the study, served as the advisor, and contributed to methodological refinement. S.H.M. assisted in data collection procedures and contributed to the interpretation of the findings. A.K. performed the statistical analyses and drafted the manuscript. All authors reviewed, revised, and approved the final version of the manuscript.

Ethical Considerations

This study was approved by the Ethics Committee of the Faculty of Sport Sciences and Health, University of Tehran (IR.UT.SPORT.REC.1402.018). All participants were informed about the study objectives and procedures and provided written informed consent before participation, in accordance with the Declaration of Helsinki.

Acknowledgment

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Conflict of Interests

The authors declare that they have no competing interests.

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